

## COMPOSITE FLOOR SYSTEM

### FIELD OF THE INVENTION

The present invention relates generally to composite steel and concrete floor systems of the type including reinforced concrete slabs supported by secondary framing members such as steel joists, which in turn are spanned across primary framing members, such as hot rolled steel, beams, girders, or trusses. More particularly, it concerns a composite concrete floor system comprising secondary framing members provided with shear shoes at their ends. These shear shoes are adapted to provide to the whole system an increased resistance to horizontal shear forces.

### BACKGROUND OF THE INVENTION

In composite floor structures, it is known to couple the concrete and steel components to provide composite action, thereby reducing the amount of material in the floor system for a given required strength. By using the concrete slab as the top chord of a composite beam, a significant reduction in the amount of steel in the floor system is achieved. Such floor systems are known in the art. One well known system of secondary members is sold as the Hambro<sup>TM</sup> structural system. This system is disclosed in US patent no. 5,544,464.

In residential buildings, it is common to arrange the structure to span open web joists between load bearing walls, and no primary framing members are required to support the joists. In larger structures, the joists are generally supported by primary framing members in the form of steel beams or trusses. This is particularly the case for steel framed buildings which are erected as steel columns connected by and supporting primary steel framing members. Secondary steel framing members, for example in the form of open web steel joists, are spanned across the primary members, and loads are transferred by the primary members to the columns, and to the foundations of the building.

These structures must resist to many forces, both horizontal and vertical and, as such, their design is complex and require the application of much scientific skill and knowledge. One of the forces encountered in these structures is known as horizontal shear. This is a horizontal force which occurs along the longitudinal

5 top of primary and secondary frame members. The Hambro™ joist described in US 5,544,464 is provided with a unique S-shaped top chord which, when embedded in the concrete slab, forms a shear connector to prevent slippage from occurring between the concrete slab and the joist, due to horizontal shear along the joist.

10 Various forms of shear connectors have been developed for the primary steel framing members, the most common being the headed shear stud, or Nelson™ stud, an elongated vertical device, which has an enlarged head, much like an oversized nail. This stud is welded to the steel beam after the beam has been connected to the structure during erection. This stud provides the necessary  
15 shear capacity between the embedded stud and the concrete slab, thereby providing a composite steel beam or girder. The stud is intended to be imbedded in the concrete, thereby transferring horizontal shear forces from the slab to the beam.

The most cost effective way to provide shear studs is to install them in the shop.

20 However, one drawback with such shear connector is that these studs constitute a tripping hazard for steel workers who have to walk on these beams during erection of the frame. The seriousness of the problem is highlighted by the fact that for more than 25 years, the International Ironworker Agreement has rejected the use of such studs on steel beams. These rules were adopted by safety  
25 committees as they were formed in Canada and the USA, such as OSHA. In order to overcome that problem, the studs are generally welded to the primary steel members on the site of construction. In such a case, the secondary framing members (also referred to as steel joists) are first installed on the primary steel member, then the steel deck is installed, and then the studs are  
30 welded through the metal decking on the steel top chord. The installation of the

shear studs on the site of construction creates quality problems due to the very nature of the welding process. Also, since the installation of these studs is weather dependant, another drawback encountered with such "on site" installation comes from the fact that it is often very difficult to schedule the 5 skilled labour required and to manage such schedule so as to follow the fast pace of structural steel erection program.

Other examples of concrete floor systems are given in US 4,729,201; US 6,061,992; US 2003/0024205; US 2003/0084629; US 4,454,695; US 4,700,519 and US 4,592,184.

10 Thus there is a need for a new form of shear connector for the primary framing members which leaves the top flange essentially flat for walking purposes, and avoids the installation and scheduling problems.

### **SUMMARY OF THE INVENTION**

In accordance with the present invention, that object is achieved with a framing system for a composite concrete floor of the type comprising horizontally extending primary framing members supporting secondary framing members spanning across the primary framing members, the primary and secondary framing members being made of a metallic structural material. Each of the 15 secondary members has two opposite ends provided with a shear shoe that is fixed to the primary members by means of a structural joint sufficient to provide a shear connection between the concrete floor and the primary framing members.

The metallic structural material is preferably steel or any other metallic structural material known in the art. The present invention is thus not limited to steel 25 framing members. Therefore, whenever reference is made throughout the present description to steel beams, steel joists, one should understand beams, joists or framing members made of a metallic structural material.

The shear shoes of the secondary members preferably consist of an iron angle having one horizontally extending face fixed by means of the structural joint to a

horizontal face of a respective one of the primary framing members, and one vertically extending face fixed to said secondary framing member.

Also preferably, the structural joint is selected from the group consisting of a weld joint and a bolt joint.

- 5 As can be appreciated, the present invention forms a mechanical shear connection for primary framing members which does not create a tripping hazard during erection and prior to the composite stage, when the concrete floor slab has been formed and is cured, which shear connection effectively transfers horizontal shear forces to the primary frame members.
- 10 Thus, the present invention provides, among other things, all the advantages of composite steel/concrete floor slab construction, with the added advantage of an efficient horizontal shear connection to primary steel floor members, allowing a continuous poured slab for an entire floor of a building to be formed with no tripping hazards for iron workers, due to shear connectors. Such a structure is
- 15 also designed by structural engineers to meet all other loads encountered in usual building construction.

In a further aspect, the present invention provides a method of assembling the framing members to concrete. The method comprises the steps of :

- providing primary and secondary framing members made of a metallic structural material, each of the secondary framing members having two opposite ends provided with a shoe;
- placing the primary framing members in parallel relation;
- placing the secondary framing members across the primary members with the shoes bearing on the primary framing members; and
- 25 -fixing the shoes to the primary framing members with a structural joint sufficient to provide a shear connection for said primary members.

Preferably, the step of fixing consists of welding the shoes to the primary framing members. Also preferably, the secondary framing members have a continuous shear connector.

More preferably, the shear connector is a continuous top chord adapted to be  
5 embedded in the concrete floor.

The present invention further provides a new end shoe concept or a novel end shoe for connecting the joist to the beam. The invention also provides a novel joist with an end shoe which serves as the shear connector for the beam to which it is attached.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

These and other objects and advantages of the invention will become apparent upon reading the detailed description and upon referring to the drawings in which:

Figure 1 is an overhead perspective view of a composite floor in accordance  
15 with the present invention, with the concrete slab partially removed to show the steel frame members;

Figure 2 is a cross-sectional view through a floor system in accordance with a first preferred embodiment of the invention, the cross-sectional view being perpendicular to a primary framing member;

20 Figure 3 is a cross-sectional view at right angle to the section of Figure 2 along line 3-3 and showing the shear force applied on a shear shoe;

Figure 4 is a cross-sectional view of the mounting of secondary frame members in the form of open web steel joists on a primary steel beam member of the floor system of Figure 2;

25 Figure 5 is a cross-sectional view of a primary frame truss supporting open web steel joists;

Figure 6 is an enlarged perspective view of the frame members of Figure 5;

Figure 7 is an end elevation view of a frame truss or joist girder for use in the floor system of the invention;

Figure 8 is an end elevation view of the joist truss supporting two joists of the present invention;

5 Figure 9 is a plan view of the joist truss supporting a plurality of open web joists of the invention;

Figures 10 and 11 are side elevation views of joist truss girders before and after the concrete has been poured;

10 Figure 12 is a plan view of a primary framing member supporting staggered secondary framing members, with end shoes welded to the primary framing member;

Figure 13 is a cross-sectional view through a floor system in accordance with a second preferred embodiment of the invention, the cross section being perpendicular to a primary framing member;

15 Figure 14 is a cross-sectional view at right angle to the section of Figure 13 along line 14-14, and showing the shear force applied on a shear shoe; and

Figure 15 is a cross-sectional view of the mounting of secondary framing members in the form of open web steel joists on a primary steel beam member of the floor system shown in Figure 13.

20 **DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION**

In the following description, similar features in the drawings have been given similar reference numerals and in order to lighten the figures, some elements are not referred to in some figures if they were already identified in a precedent figure.

25 Referring to Figure 1, there is shown, in perspective, an overhead view of a composite floor system of the invention. A primary framing member 11, which is

shown here as a steel truss or girder, supports a plurality of secondary framing members 12 formed as open web steel joists which span perpendicularly between adjacent primary framing members (not shown). Each joist 12 is provided with an end shoe 13 on each end of the joist for attachment to the  
5 primary framing member 11. Figure 6 shows this in greater detail, as explained below. Preferably, the primary framing member 12 used is a Hambro™ joist provided with an S-shaped top chord which forms a shear connector between the primary framing member 12 and the concrete slab 14. A concrete slab 14 with reinforcing mesh 15 is poured onto form-work (not shown for simplicity) and  
10 embeds the top chord 16 of the joists 12 and the top chord 17 of the primary framing members 11. The end shoes 13 of the joists 12 are fixed to the primary framing member 11 by means of a structural joint 15 sufficient to provide a shear connection between the concrete floor 14 and the primary framing members 12. The shear shoe thus acts as a shear connector able to transfer the horizontal  
15 loading from the slab to the primary framing member by the end shoe structurally fixed to the primary framing member 11. The structural joint 15 is preferably a weld joint between the shear shoe 13 and the primary framing member 11, the weld having a length sufficiently long so as to provide such structural joint. Although not simple, the determination of shear capacity  
20 between two components is of common knowledge for a person in the art. Hence, such person, having knowledge of the forces applied on the floor, the length and height of the primary and secondary framing members used for the floor system, knows how to calculate the shear necessary to develop the composite action between secondary and primary framing members and the  
25 right spacing between the connectors. As for example, in one preferred embodiment, an end shoe Hambro D500™ with a concrete slab of 2  $\frac{3}{4}$  inches reinforced by a wire mesh 6 x 6 6/6 fixed to the primary framing members by a weld of at least 2 inches provided on each side of the shoe can provide a capacity of 30.2 Kips per shoe. The total capacity provided will be the number of  
30 shoes installed on the primary framing member by 30.2 Kips per shoe.

Figure 2 shows a primary framing member in the form of a steel beam 11' supporting a joist 12 fitted with an end shoe 13 welded to the beam 11'. This weld is shown in greater detail in Figure 6 below. The end shoe 13 is also referred to hereinafter as a "shear shoe".

- 5 In Figure 3, the same beam 11' as shown in Figure 2 is shown in elevation, with the arrow 20 indicating the direction of the horizontal shear force. The combination of the joist 12, the end shoe 13 and the welding of the end shoe 12 to the primary member 11 creates a shear connector to resist the horizontal shear forces between the slab 14 and the primary framing member 11 or 11'.
- 10 The advantages of this new shear connector are many. First, there is the utilization of the joist end shoe 13 designed and analyzed to provide a bond included in each secondary framing member 11. The shear shoe 13 performs a double function of supporting the gravity load on the joist and also provides a mechanical shear connector able to transfer the bond between the slab 14 and the primary framing member 11. This type of shear connection also avoids the tripping hazard on the site, according to labour union rules, and increases 15 erection speed of the steel building frame.

The present invention features the use of special ends or shear shoes 13 which act as shear connectors to the flange of a steel beam or the top chord of a truss.

- 20 The shoe 13 is also a gravity shoe for the secondary steel framing member 12 and shear connector tested and designed according to the capacity required for the composite trusses. The welding between the top chord of the truss or beam forming the primary framing member 11 and the shoe 13 is designed according to the capacity required. The open web joist of the secondary framing members 25 12 can be used in a deck-slab system such as Hambro MD2000<sup>TM</sup> system or with a removable plywood system such as Hambro D500<sup>TM</sup>.

Depending on the loading and span of the primary framing member 11, single shoe connectors 13 can be used, or groups of connectors. The total capacity in bond will be the total capacity of all shoe connectors and other connectors.

Figure 4 illustrates a pair of open web joist secondary members 12, which may be aligned or staggered, mounted on a primary framing member 11. Each joist 12 is provided with a dual purpose shear shoe 13 which is welded to the joist 12 in manufacture, and delivered to the job-site, ready for installation. Each shoe 13 is then welded or bolted to the top flange of the regular beam primary framing member 11. Similarly, Figure 5 illustrates a pair of joists 12 with shear shoes 13 mounted on a primary truss framing member 11. As before the shoes are welded to the top flanges of the truss 11. In both of these cases, horizontal shear between the primary framing member and the slab is transferred from the slab to the primary framing member by the shear shoes 13.

Figure 6 is a perspective view from above of the connection of the secondary open web joists 12 and the primary truss framing member 11. Welds 21 are provided on both sides of shear shoes 13 to fix the shoes 13 to the top flanges of the truss 11.

Figure 7 is a vertical section of a primary steel truss framing member 11 consisting of a bottom chord formed of angles 30 welded back-to-back between web members 32 which in turn are welded to a gusset plate 32 which in turn is welded to a back-to-back top chord angle 33. The vertical legs of the angles 33 are slotted at intervals, the slots being staggered, and rod segments 34 are welded to the vertical legs of the angles 33.

This novel truss construction provides a strong, light primary framing member with maximum openings in the web through which building services such as heating, plumbing, electricity, and communication services can be located. Figure 8 shows the connection of primary and secondary framing members using the truss of Figure 7, integrating the whole frame structure to resist horizontal shear forces, and support the gravity load of the floor system.

Figure 9 is a plan view of a portion of a floor frame system 10 including a primary truss 11, and secondary joists 12 with end shoes 13, in which the joists are aligned rather than staggered.

Figures 10 and 11 show alternate truss configurations depending on building requirements, Figure 10 being the standard configuration and Figure 11 being a configuration for maximum size openings in the truss for accommodating large ducts.

5 Figure 12 is a plan view of a primary steel beam framing member 11 supporting staggered secondary open web joist members 12 with shear shoes 13 welded to the member 11. Such staggering of the secondary members is required when shear connectors are required at intervals less than the normal joist spacing.

Referring to Figure 13, a concrete floor system according to a second preferred  
10 embodiment of the invention is illustrated. As for the first preferred embodiment shown in Figure 2, the floor system comprises a primary framing member in the form of a steel beam 11' supporting a joist 12 fitted with an end shoe 13 welded to the beam 11', the whole structure supporting a concrete floor 14. The difference between the first preferred embodiment shown in Figures 2 to 12 and  
15 the second embodiment resides mainly in the fact that, in the first embodiment, the shear shoes 13 are embedded in the concrete, whereas the shear shoes 13 in the second embodiment are not, the concrete being poured on top of the secondary framing members 12.

In Figure 14, the same beam as shown in Figure 13 is shown in elevation, with  
20 the arrow 20 indicating the direction of the horizontal shear force. The combination of the primary framing member 12, the end shoe 13 and the welding of the end shoe 13 to the primary framing member 11 creates a shear connector to resist the horizontal shear forces between the slab 14 and the primary framing member 11 or 11'.

25 Although preferred embodiments of the present invention have been described in detail herein and illustrated in the accompanying drawings, it is to be understood that the invention is not limited to these precise embodiments and that various changes and modifications may be effected therein without departing from the scope or spirit of the present invention.